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Analysis of Postures, Perceived Physical Safety, and Technology Acceptance of Immersive Exergames Among Older Adults

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Abstract: Recent studies have increasingly focused on using virtual reality (VR) exercise video games (exergames) to boost motivation for physical activity among the elderly. However, there is little discussion about the factors influencing the performance and effort expectancy of immersive exergames in older adults. The study was based on the Unified Theory of Acceptance and Use of Technology (UTAUT) model. UTAUT model was tested and extended by investigating two predicted factors—Physical Safety (PPS) and Physical Postures (PP)—of immersive exergames among older adults. PP, PPS, Performance Expectancy (PE), and Effort Expectancy (EE) relationships were analyzed. In this study, 40 healthy older adults were divided into 2 groups to play an immersive exergame for at least 5 min, either sitting or standing. Then, a list of measurement items based on the extended UTAUT model was completed by one-on-one interviews. The *t*-test results showed that PP was significantly correlated with PPS (t = −6.598, $p < 0.001$) and PE (t = 6.465, $p < 0.001$). The path analysis showed that PPS as a negative correlation was verified as a factor of PE ($\beta = -0.438$, $p < 0.01$). Both PP and PPS had no significant effect on EE. Overall, valuable insights and theoretical guidelines for older adults accepting immersive exergames are supported in this study.

Keywords: older adults; immersive exergame; technology acceptance; perceived physical safety; physical posture; performance expectancy; effort expectancy

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1. Introduction

The rapidly increasing elderly population has led to a challenge in the management of a healthy aging environment and functional ability [1]. Physical activity is known to be an efficient method for improving the walking, standing, muscle strength, and balance skills of older people, thereby decreasing the risk of falling and enhancing their quality of life [2–4]. Exergames, a blend of “exercise” and “games,” are digital or video games created to encourage physical activity by incorporating exercise into the gaming experience. These games use interactive technology, such as motion sensors, cameras, or wearable devices, to involve players in physical movements, promoting exercise as part of the gameplay. Recently, immersive technology-based exergames (IEG), such as virtual reality (VR) and augmented reality (AR) technologies, to enhance older adults’ physical health and quality of life have been widely considered as effective interventions. The fact that VR exergames can effectively enhance balance and physical mobility in the elderly has been validated by several studies [5–7].

Positive acceptance and attitudes of older people have been reported in many exergames studies [8–11]. Performance expectancy (PE) and effort expectancy (EE) as the constructs of the unified theory of acceptance and use of technology (UTAUT) have been proven to have an impact on the intention to use [12]. However, little information is available on the factors that would influence older people's PE and EE in IEG. This study focused on the understanding of physical postures (PP), perceived physical safety (PPS), and extended PE and EE constructs of UTAUT of immersive exergames among older people.

2. Literature Review

According to the reports from the Office of Disease Prevention and Health Promotion (ODPHP), 31 million adults age 50 or older were inactive with physical activities in 2014, the data from 2018 indicated that 37.3% of the population aged 65 and over engaged in no leisure-time physical activity (National Health Interview Survey) [13]. The slow increase of the data from 2008 to 2018 indicated that the awareness of healthy aging and the value of physical activities in leisure time is growing for the older population. However, after the COVID-19 pandemic, the unconfident and fear of the exercise environment and my own health conditions lead to a loss of trust to do exercise [14].

To support exercise intervention for older people, IEGs have been developed to reduce limits of distance, space, human resources, and entertainment, and many studies have reported the effectiveness of these IEGs [5,7,15,16]. Immersive technology and exergames have been developing rapidly over the past decade, and their benefits have been launched [17–21]. Many different types of IEG are designed and tested for older people, usually to address a specific need in the context of disease management (e.g., Parkinson's disease and stroke), safety, presence, or access. Most of the studies used a specific solution to address the needs of patients or older users, such as chronic disease management, rehabilitation training, fall prevention, and balance challenges [22–24]. For example, Karaosmanoglu and his team developed Canoe VR, an immersive exergame to support older adults' physical exercises, which has been well-received as an additional fitness tool [25]. Liepa's findings indicate that using a VR exergame to exercise could improve both cognition and functional mobility among older adults [15]. Regarding the acceptance and usability of IEG, for instance, studies have reported positive experiences and perceived the technology as useful and easy to use, with little heightened gaming-related anxiety among older adults [26,27]. Some studies have compared different factors of immersive exergames. The results from Stamm's team's work indicate that usability and acceptance are not related to the type of training when using MR exergames with older adults [28]. Additionally, the physical environment in this study was designed to match the environment in the game developed by the team. Shah's team found that older adults preferred direct hand manipulation for interaction with virtual objects in immersive exergames, finding it more engaging and less cumbersome [8].

Although IEG for older adults shows a promising future, relevant perceptual factors are rarely discussed. The factors influencing the performance and effort expectation of playing exergames through immersive technologies such as virtual reality technology, remain less explored. A negative or passive attitude of perceived effort and performance would hamper the application of the immersive technology and experience benefits. Thus, it is necessary to understand the factors that specifically influence and how they can predict the perceived effort and performance of doing exercise through immersive exergames among the older population. There have been studies that examined the acceptance of health technologies among older adults using the unified UTAUT model [12] as the theoretical foundation and further extended contextual-specific predictors in various types of health technologies [29–32]. These studies determined and examined several focal constructs including performance expectancy (PE), effort expectance (EE), social influence (SI), and facilitating conditions (FC). Self-efficiency, computer anxiety, perceived security, and doctors' opinions have been investigated in these studies. However, factors related to safety (e.g., perceived safety and physical posture through IEG should be considered, because these factors are widely associated with older adults' acceptance, choice, and use of a certain health-related technology [33–36]. Evidence regarding the role of PP and PPS as UTAUT constructs in the context of the study still needs to be investigated. In addition, their influence on the PE and EE of older people performing exercises through VR games also needs to be discussed.

In this study, a theoretical model was developed to investigate the roles of perceived physical safety, physical postures, performance expectancy, and effort expectancy within the UTAUT model regarding the acceptance and intended use of IEG by older adults.

3. Theoretical Framework and Hypotheses

The conceptual framework of the study is depicted in Figure 1, which has been constructed by extending the foundational UTAUT model. This adaptation includes the integration of two novel human-centric factors—physical posture and perceived physical safety—into the existing constructs of PE and EE. These additional dimensions are posited to exert an impact on the acceptance, performance expectation, and effort expectation of immersive exergaming by older adults. The rationale for the inclusion of these factors is predicated on the premise that physical interaction and safety perceptions are critical factors in the adoption of technology-intensive physical activity interventions among older adults.

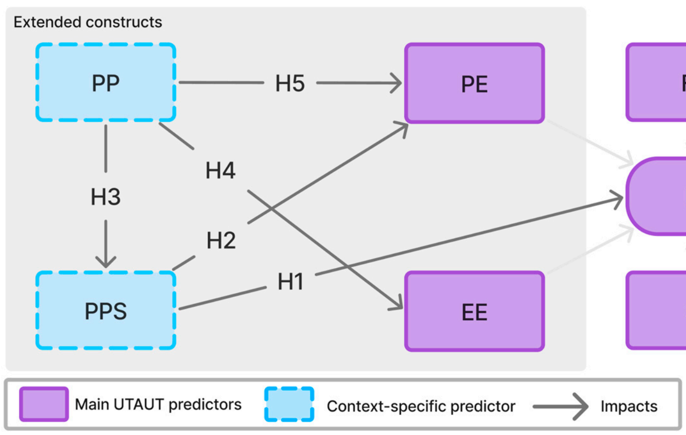

Figure 1. PP and PPS for predicting older users' PE, EE, and BI of IEGs. Note. PP: Physical Posture, PPS: Perceived Physical Safety, PE: Performance Expectancy, EE: Effort Expectancy, FC: Facility Condition, SI: Social Influence, BI: Behavioral Intention to use.

3.1. UTAUT Model and Universal Constructs

Several theory models have been proposed to investigate the factors influencing user acceptance and use behavior intention, including the Technology Acceptance Model (TAM), Health Information Technology Acceptance Model (HITAM), Unified Theory of Acceptance and Use of Technology (UTAUT) model, and the Extended UTAUT model of older users' home telehealth services. UTAUT model served as the foundational theoretical framework for this investigation due to its demonstrated applicability in elucidating the factors influencing individuals' acceptance and intention to utilize specific technologies. This relevance extends to domains concerning health and aging, making it particularly suited for examining the adoption behaviors towards technology-driven interventions among older populations [12,32,37,38]. The UTAUT model's robustness in capturing the multifaceted nature of technology acceptance, including aspects related to performance expectancy, effort expectancy, social influence, and facilitating conditions, renders it an ideal basis for exploring how these constructs influence the acceptance and behavioral intention (BI) of health-related technologies by the elderly. In this study, BI refers to the strength of an individual's intention to perform exercises through IEG in the future, which is a measure to indicate the acceptance and intention to use IEG. Performance expectancy (PE) is defined as the degree to which individuals believe that using IEG will help them to attain gains in their physical activity performance and enhance their quality of life. Effort expectancy (EE) presents the degree of ease associated with the use of IEG for the older population. Social influence (SI) refers to the degree to which individuals perceive those important individuals who believe they should exercise through immersive technologies. Facilitating conditions (FC) are defined as the degree to which older people believe that the organizations and technical infrastructure exist to support the use of IEG.

3.2. Perceived Physical Safety

Perceived physical safety (PPS) is conceptualized as an individual's subjective perceptions of their vulnerability to physical harm or danger in a specific physical environment or situation [39]. In the present study, PPS refers to older adults' perceptions of their body, environment, and health condition safety during performing exercise through IEG. Based on the literature, PPS would positively influence BI in the fields of human-computer interaction, human-robot interaction, occupational exoskeletons, and immersive exergames usage [40–43]. Braune., alt, proposed a concept- attitude towards health. The Domain-Specific Risk-Taking (DOSPERT)scale, including six items of nutrition, smoking and drinking, sleeping, physical inactivity, and hectic lifestyle, was used in the research to extend the UTAUT model [44]. The focus was on long-term health condition awareness among older people instead of the current feeling when performing exergames. Additionally, according to current studies, perceived safety can be described in three conditions: perceived safety of the physical environment, and cognitive and emotional body safety. Usually, perceived safety refers to an assessment of the certain environment and situation where the individual is present. However, the virtual world will lead to two spaces simultaneously during playing IEG. The perceived safety of the physical environment has been reported to be a significant item in the intention to perform physical activities among the older population [45,46]. Although most published empirical studies often measured perceived safety as a unidimensional construct, perceived safety can be conceptualized as a multidimensional construct composed of both a cognitive component and an emotional component [47]. In the study, older adults' cognitive safety refers to the degree of feeling of injury risk to the physical body and risk of stimuli to their existing health condition (e.g., chronic disease or latent disease). On the other hand, the emotional perceived safety refers to feeling harmony or an anxious inner body while playing IEG among older people. In the study, we hypothesized that older adults may tend to show higher intention to play IEG if they believe it is highly safe.

Hypothesis 1 (H1). *PPS positively influences BI.*

Based on the results of some reviews, it appears that older adults are more likely to perceive insecurity in exercise games using Wii Fit® and balance boards compared to other exergames [48]. However, the results of some studies have shown that older adults in a standing position using exercise games on the Wii, Balance Board, or Xbox Kinect report higher perceived usefulness. Wang's study showed that the adventure-fit game genre through Kinect is preferable to other games for older people [49]. Yein and Pal used Dance Dance evolution (DDR) in which older females had to be more careful to keep up with the pace while following the arrow, and the response demonstrated the feelings of usefulness and high-performance expectation of their health [50]. Therefore, in this study, we hypothesized that older adults may tend to show lower performance expectancy of IEG if they believe it is highly safe.

Hypothesis 2 (H2). *PPS negatively influences PE.*

3.3. Physical Posture

PP in the context of the study is referred to as the physical posture when older adults play IEG (e.g., standing or sitting). In case of confusion between the postures of the body and the virtual avatar, physical posture was used to describe the body position.

The various postures adopted by elderly individuals during physical exercise, such as standing and sitting positions, can influence the degree to which energy expenditure is increased in this demographic [51]. Because the majority of physical activities require an upright posture, and considering that low-intensity physical activities have been demonstrated to be beneficial for the safety issues and functional abilities of the elderly, it is pertinent to the body positions guideline of the traditional exercise among the aged. These guidelines often recommend a combination of seated exercises targeting the upper body musculature and standing exercises that engage multiple muscle groups throughout the body [52,53]. Some studies have shown that particularly for frail older adults, seated exercises are a more sustainable form of physical activity, especially for frail older adults, as the risk of falls can be greatly reduced [52,54]. Therefore, PP may influence physical safety during exercise in older adults.

Hypothesis 3 (H3). *Seated IEG has a higher PPS than upright IEG.*

Furthermore, the methods for measuring the amount of physical activity among the elderly include objective instruments (e.g., accelerometers and heart rate monitors) as well as self-reports by the elderly participants. Some studies have reported that data obtained through instrument measurements are more objective. However, in activities performed in a standing position, the self-reported results by the elderly tend to be exaggerated compared to the actual data [55]. In some studies, it has been reported that a portion of the elderly population considers merely standing and walking as forms of physical activity [54,56]. Therefore, from the perspective of these elderly individuals, the intensity of effort expected for upright IEG may be perceived as higher than that for seated activities.

Hypothesis 4 (H4). *Upright IEG has a higher EE than seated IEG.*

Due to the fact that playing IEG while standing activates a greater number of muscle groups and results in higher energy expenditure during physical activities, practitioners may believe that exercising through upright IEG is more effective.

Hypothesis 5 (H5). *Seated IEG has a lower PE than upright IEG.*

4. Materials and Methods

4.1. Participants

The study sample comprised 40 Chinese senior participants (20 women, 20 men), aged 60–88 years (mean age 69.6, SD 7.4 years). Among the 40 participants, none had experience playing VR games before, although nearly half reported having a basic understanding of VR technology. Therefore, none of the participants had actually used a VR game prior to this study. The exclusion criteria were rigorously defined to ensure the safety and appropriateness of the study interventions for all participants. Individuals were excluded if they presented absolute or relative contraindications to physical exercise. Additionally, exclusion was warranted for those who were unable to comply adequately with the assessment protocol, as determined by clinical evaluation. Potential participants were considered ineligible if they had cardiovascular, pulmonary, or musculoskeletal disorders that, in the opinion of their medical professionals, could compromise their ability to safely and effectively engage in the study activities. Additionally, individuals with severe visual impairments that might hinder their interaction with the immersive virtual reality simulation, as well as those with a history of vertigo, epilepsy, or psychosis, were excluded from participating in the research.

4.2. Stimuli

The present research utilized Fruit Ninja VR as the exergame of choice to examine both universal and contextual-specific determinants within the UTAUT framework. Empirical evidence has substantiated the efficacy of Fruit Ninja VR as a virtual reality exergame in augmenting physical exertion and cognitive well-being among the elderly population [57–59]. This particular exergame requires participants to engage in arms and hand movements, simulating the action of wielding virtual swords to cut through projected fruit targets. This game primarily involves upper arm movements, which are ideal for our study as they provide a consistent form of physical activity without the variability introduced by full-body movements. This form of game mechanism reduces the variability in lower limb movements between the two postural groups in this study because participants in the standing group also did not require the same lower limb movements as the seated group. In the immersive VR environment, the participants used a head-mounted display (Meta Quest 3®) to play the exergame.

4.3. Procedure

Before the commencement of the investigation, the research team meticulously prepared the experimental settings for the subjects. This preparation will include the provision of a virtual reality headset, a chair equipped with armrests, and a designated area with minimum dimensions of 3 m × 3 m as shown in Figure 2. Subsequently, the participants received comprehensive instructions and short training on the utilization and play of the virtual exergame. Following the instructional session, the participants were directed to perform a series of tasks within the exergame with physical activities according to the guidelines stipulated by the researcher. The playing tasks lasted 5 to 15 min, which was decided by the participants for safety considerations, and they were asked to perform the exercise for at least 5 min and then stop at any time they required. Throughout the entire process, an assistant provided one-on-one supervision to ensure participants' safety and protect them from any potential risks. The participants in the study were stratified into two distinct cohorts: one designated as the sitting group (SIG) (n = 20), wherein individuals performed the activities while seated, and the other referred to as the standing group (STG) (n = 20), wherein participants engaged in the tasks while standing. Throughout the study, the researcher conducted video recordings to capture the proceedings in their entirety. After exergaming, each participant will be assisted by a research assistant to complete an Extended UTAUT list of measurement items on a one-to-one basis. Due to the older adults' low reading abilities and poor vision, each participant was interviewed by the researcher following the questions. This will facilitate the collection of data pertaining to participants' experiences and responses to the exergame intervention.

The study was conducted in a community in Wuhan, China. Written consent from all participants was assessed for eligibility criteria and then take part in the short training.

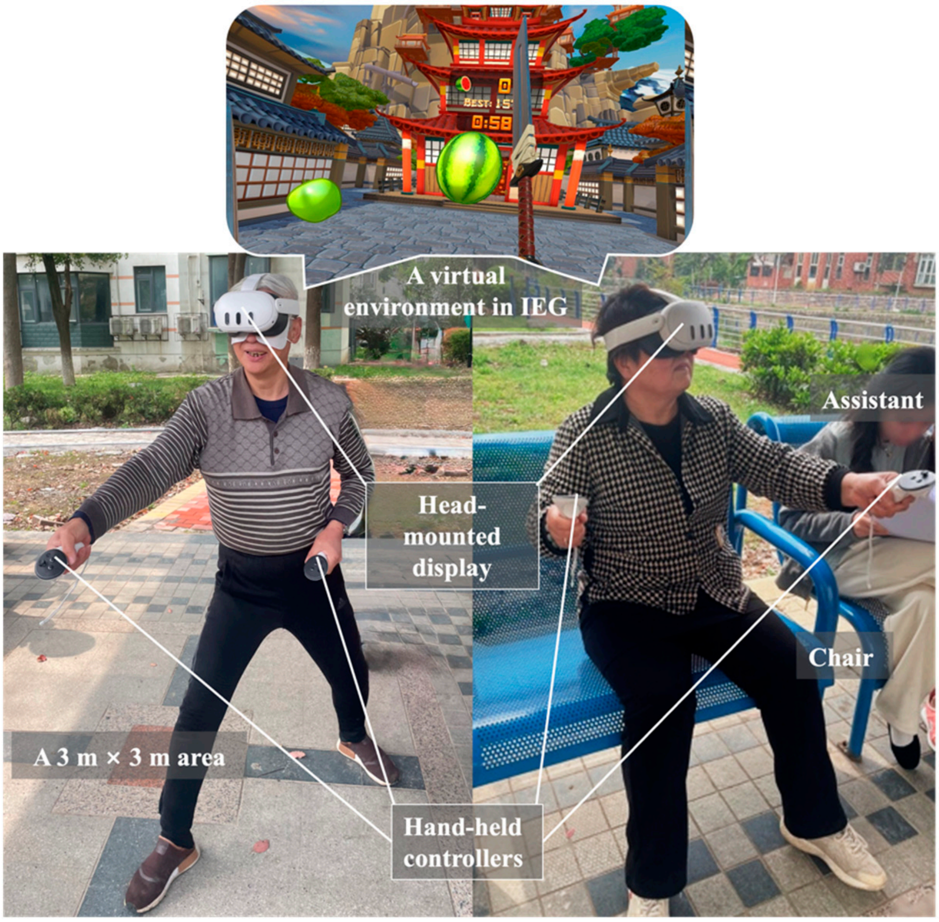

Figure 2. Virtual environment in Fruit Ninja VR.

4.4. Outcome Measurement

Based on the literature [29,30,32], the list based on the extended UTAUT model was used to measure PE, EE, and BI constructs of performing IEG. According to the studies [48,60,61], the measurement items of the PPS construct include feelings about the inner body and physical environment. The measurement items are presented in Table 1. PPS1, PPS2, and PPS4 measure the subjective safety of the physical body, while PPS3 focuses on the physical environment. PPS2 emphasizes the "comfort" feeling, and PPS4 emphasizes the "trust" feeling, especially about their existing worries about health issues and chronic pain, which are directly related to perceived safety. The items of each construct are rated on a 7-point Likert scale, ranging from 1 (very strongly disagree) to 7 (very strongly agree).

Table 1. Measurement items of hypothesis constructions.

Constructions	Measurement Items
Performance Expectation (PE)	PE1: I find that playing VR exergames helps me with my functional mobility. PE2: I find that playing VR exergames would make me feel healthier in my daily life. PE3: VR exergames could enhance my muscle strength. PE4: VR exergames could enhance my balance skills. PE5: VR exergames are helpful to enhance my confidence in exercising. PE6: Overall, I find VR exergames would be highly helpful.
Effort Expectation (EE)	EE1: I find that playing VR exergames would be simple. EE2: I find that playing VR exergames would be easy to learn. EE3: I find that VR exergames would be easily understandable and clear to me. EE4: Overall, I find VR exergames would be convenient.

Table 1. *Cont.*

Constructions	Measurement Items
Perceived Physical Safety (PPS)	PPS1: I would feel my body safe while playing VR exergames. PPS2: I would feel in harmony with my body while playing VR exergames. PPS3: I feel that I'm in a safe physical environment while playing VR exergames. PPS4: I trust in my body's health condition while playing VR exergames. PPS5: Overall, I find VR exergames would be safe.
Behavioral Intention to Use (BI)	BI1: Assuming I had access to a VR exergame, I would intend to use it. BI2: I predict I will play VR exergames on a regular basis in the future. BI3: I intend to play VR exergames in the future. BI4: Given that I had access to a VR exergame, I would play with it to keep healthy.

4.5. Data Analysis Method

The participants' demographic characteristics (gender and age) and their responses to measurement items were summarized using descriptive statistics, including mean and SD. The reliability and validity of the measurement items were assessed using Cronbach's alpha by assessing internal consistency (the acceptable value should be higher than 0.7).

The results include the correlation analysis, the path analysis of PPS, PE, EE, BI, age, and gender, and the *t*-test of PP, PPS, PE, and BI constructs. Correlation analysis was used to measure the correlation of the constructs. Next, linear regression analysis was used to examine the path coefficients (β) and significance levels. To examine the two postures' impact on PPS, PE, and BI, we used an independent sample *t*-test for both STG and SIG groups. Additionally, an independent samples *t*-test was conducted to examine whether significant differences exist between males and females.

5. Results

5.1. Result of Correlation Analysis and Path Analysis

Cronbach's alpha was used to assess the internal consistency of each construct. Table 2 shows a high level of internal consistency of four constructs, suggesting the satisfactory reliability and validity of the measurements.

The results of measurement items' mean values and standard deviation values are described in Table 2. The results show that the means of EE and PPS items are at a high level above 6.00 (with the highest level at 7 points). Most of the participants expressed their acceptance and intention to use IEG in the future. Most of the items' SD is lower than 1.00 which indicates that participants' opinions are similar. A higher level of SD is reported in PE4 (SD= 1.130) and BI 2 (SD = 1.122), which indicates moderate variables by participants expressed in these items.

Table 3 shows the correlation results of PE, EE, PPS, BI, and age. Overall, the correlation analysis revealed significant relationships between PE and PPS, PE and BI, EE and age. A significant positive correlation is observed between PE and BI at a high level of statistical significance ($p < 0.01$). Additionally, a significant negative correlation is found between age and EE at $p < 0.05$. The result indicates that: 1. age is negatively correlated with effort expectancy, meaning that younger people are more likely than others to find the immersive exergames easy to play; 2. PE is negatively correlated with PPS, indicating that individuals who feel safer during physical activities have lower performance expectations. In contrast, individuals who think less physically safe tend to be more focused on the expectation of attaining health benefits; 3. PE is positively correlated with BI, indicating that older adults with higher performance expectations in immersive exergames are more likely to use IEG in the future.

Table 2. Basic descriptive results of interviews based on the extended UTAUT of 40 participants.

Constructs	Items	Mean	SD	Cronbach's Alpha (α)
PE	PE1	5.85	0.864	0.881
	PE2	5.93	0.859	
	PE3	6.03	0.862	
	PE4	5.83	1.13	
	PE5	5.9	0.871	
	PE6	6.05	0.815	
EE	EE1	6.58	0.55	0.831
	EE2	6.63	0.585	
	EE3	6.53	0.64	
	EE4	6.65	0.483	
PPS	PPS1	6.43	0.595	0.854
	PPS2	6	0.877	
	PPS3	6.23	0.733	
	PPS4	6.4	0.632	
	PPS5	6.53	0.554	
BI	BI1	6.1	0.982	0.906
	BI2	5.9	1.122	
	BI3	6.2	0.974	
	BI4	6	0.832	

Note. PPS: perceived physical safety; EE: effort expectancy; PE: performance expectancy; BI: behavioral intention.

Table 3. Correlation analysis results between constructs and age in the whole, STG, and SIG groups.

Constructs	PE	EE	PPS	BI	PE (STG)	EE (STG)	PPS (STG)	PE (SIG)	EE (SIG)	PPS (SIG)
EE	0.050									
PPS	−0.438 **	−0.125								
BI	0.457 **	0.156	0.031							
Age	0.059	−0.361 *	−0.054	−0.015						
EE(STG)					−0.409					
PPS(STG)					0.237	−0.458 *				
BI(STG)					0.049	−0.204	−0.104			
EE(SIG)								0.342		
PPS(SIG)								0.422	−0.050	
BI(SIG)								0.636 **	0.339	0.365

Note. PPS: perceived physical safety; EE: effort expectancy; PE: performance expectancy; BI: behavioral intention; STG: standing group; SIG: sitting group (* $p < 0.05$, ** $p < 0.01$) (2-tailed).

Table 4 shows the results of the path coefficients' estimates and the results of H 1 and H 2 in developing the structure model. The results of path analysis of the impacts of PE, EE, and PPS on BI are not significant.

Table 4. Path coefficients (β) and structure model results.

Hypothesis	Factors	Path Coefficient (β)	t	Sig.	Support or Not
H1	PPS → BI	0.031	0.190	$p > 0.05$	No
H2	PPS → PE	−0.438 *	−3.004	$p < 0.05$	Yes

Note. PPS: perceived physical safety; EE: effort expectancy; PE: performance expectancy; BI: behavioral intention (* $p < 0.05$).

5.2. Results of t-Test and Structure Model

Table 5 describes the means and standard deviations for the construction items from the standing group and sitting group. All the means of PPS and EE for SIG, with the exception of EE3 and EE4, are confirmed to be higher than the means for STG. All the means of PE items for STG are higher than the means for SIG.

Table 5. Basic descriptive results of measurement items for STG and SIG.

Variable	STG (n = 20)			SIG (n = 20)		
		Mean	SD		Mean	SD
Male	10			10		
Female	10			10		
Mean age (years)		71.25	7.25		67.90	7.25
PPS1		6.05	0.51		6.80	0.41
PPS2		5.55	0.76		6.45	0.76
PPS3		5.80	0.70		6.65	0.49
PPS4		6.05	0.60		6.75	0.44
PPS5		6.10	0.44		6.95	0.22
EE1		6.50	0.61		6.65	0.49
EE2		6.50	0.61		6.75	0.55
EE3		6.55	0.60		6.50	0.69
EE4		6.65	0.49		6.65	0.49
PE1		6.35	0.67		5.35	0.74
PE2		6.30	0.73		5.55	0.83
PE3		6.55	0.60		5.50	0.76
PE4		6.55	0.51		5.10	1.12
PE5		6.35	0.59		5.45	0.89
PE6		6.55	0.51		5.45	0.89

Note. SD: standard deviation; PPS: perceived physical safety; EE: effort expectancy; PE: performance expectancy.

To examine potential gender differences in PE, EE, PPS, and BI, an independent samples *t*-test was conducted. The results in Table 6 indicated no significant gender effects on PE, EE, PPS, or BI.

Table 6. Independent sample T-test analysis of gender differences in PE, EE, PPS, and BI.

Independent Variable	Dependent Variable	t	Sig.
Gender	PE	0.767	$p > 0.05$
	EE	−2.452	$p > 0.05$
	PPS	1.718	$p > 0.05$
	BI	1.285	$p > 0.05$

Note. PPS: perceived physical safety; EE: effort expectancy; PE: performance expectancy; BI: behavioral intention; STG: standing group; SIG: sitting group (2-tailed).

Table 7 shows the T value and structure model results. Standing posture impact on PPS is more significantly negative than sitting postures ($t = -6.958$, $p < 0.001$). Standing posture has a more significant positive influence on PE than sitting posture ($t = 6.465$, $p < 0.001$). This indicates that seated-immersed exercisers have higher perceived safety than standing exercisers. In contrast, standing-immersed exercisers have higher performance expectations and expect IEG to bring them better and healthier outcomes.

Table 7. T-tests and structure model results.

Hypothesis	Variable	PP	t	Sig.	Support or Not
H3	PPS	STG SIG	−6.958 ***	$p < 0.001$	Yes
H4	EE	STG SIG	−0.954	$p > 0.05$	No
H5	PE	STG SIG	6.465 ***	$p < 0.001$	Yes

Note. PP: physical posture; PPS: perceived physical safety; EE: effort expectancy; PE: performance expectancy. All tests are two-tailed *t*-tests (*** $p < 0.001$).

The structure model results are shown in Figure 3. Overall, the extended model constructs PP and PPS yield acceptable discriminant validity with PE. This research yields an extended UTAUT model for PPS and PP as two factors predicting PE.

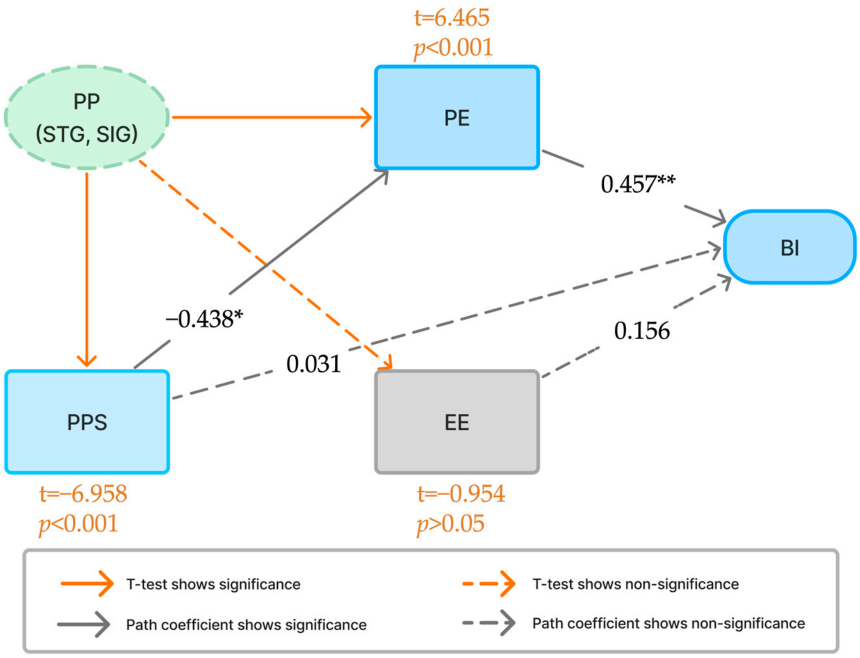

Figure 3. Path analysis and *t*-test results of PP, PPS, PE, and PE of IEG among older adults. Notes. (* $p < 0.05$, ** $p < 0.01$).

6. Discussion

6.1. Universal UTAUT Constructs

Overall, older adults were receptive to the immersive exergame via virtual reality technology, finding it easy to understand, and none of the participants reported incomprehension of the mechanics of the exergame. Participants reported that they believed immersive exergames would provide them with health benefits and increase their confidence in exercising after regular usage. Regarding perceived physical safety, surprisingly, all older adults reported feeling in a very safe physical environment and self-perceived being very reassured about their physical health, with their bodies feeling very pleasant and relaxed. This may be related to the fact that the participants in the study had more contact experience with the technology than those in the previous study. All participants reported using smart mobile devices, and five interviewees mentioned during the interviews that they had prior experience playing computer games. On the other hand, the crowd surrounding and voice during the exercise may have had some emotional as well as environmental ambiance stimulation and influence on the participants. Seated exercise users had a higher perceived sense of security than standing exercise users but brought significantly lower performance expectancy to the immersive exergame.

However, some methodological issues need to be discussed before the results can be interpreted. The number of subjects was small, so we must be careful in interpreting the results. In this sense, these analyses are only exploratory and need to be confirmed in future, more convincing studies.

In this study, we applied the UTAUT model to test the acceptance factors of older adults performing immersive exercises with virtual reality technology and tested the effects of different exercise postures—sitting and standing—on various structures in the model. Also, perceived physical safety was tested and examined as an extension of the structures in the UTAUT model in this project.

The majority of participants reported finding the immersive exergame to be very easy, and general scores on the EE were shown to be high. This may be related to the choice of game and the fact that one researcher performed VR assistance during the experience. The study found that the older seniors reported immersive exergames as simple and easy to understand, which may be related to their prerequisite perception. Computer anxiety and mental fear of 3D experience have been investigated in many studies [62,63]. Before testing, senior older adults perceived exercising with virtual reality technology to be complex; however, in the post-test, they reported the immersive exergame to be much simpler than they assumed it would be. This may be the probable reason why older adults came up with the result that immersive exercise was so simple. This is in contrast to feedback from other virtual reality games that do not use exercise as a benefit, where older adults in more narrative and task-exploration types of game interactions were less responsive and understanding than younger participants [64]. During the interviews introducing immersive technology, half of the participants expressed concerns about their ability to understand and use VR. 'I'm not sure if I can figure out how to use it'. Therefore, the ease of comprehension of the immersive exergame may not be a barrier to future immersive exercise acceptance among older adults.

PE of IEG has a positive influence on older adults' intention to use IEG. Most older adults believe that IEG can help them build stronger muscles. While seated participants also recognize the benefits of IEG for improving balance and mobility, their ratings are lower compared to those of standing participants. Nevertheless, in terms of intention to use, regular use and health-related intentions scored lower than other items. During the interviews, older adults indicated that the entertainment value of IEG has a greater impact on their willingness to use it compared to its health benefits. Furthermore, during the interviews, older adults identified two more key factors affecting their adoption of IEG: the cost and the perspectives of younger family members. Despite the interviewer's emphasis that the device was contingent on access to the required prerequisites, participants frequently raised concerns about the high cost of the equipment. For instance, one participant remarked, 'If it's not too expensive, I'd like to purchase a set for home use', while another inquired, 'Is this game costly?' The favorable attitudes of younger family members toward IEG appear to positively influence older adults' willingness to adopt the technology. Six respondents noted, 'If I play with my grandchildren, they would certainly enjoy it'. Nevertheless, one participant voiced concerns about their grandchild's potential overuse of IEG, fearing it might negatively impact their vision.

6.2. Perceived Physical Safety and Physical Posture

In terms of PPS, this study provides insights into assessing perceived physical safety in immersive exercise for older adults. Previous models of technology acceptance among older adults lacked a theoretical construct of perceived physical safety as a conceptual factor within the domain of immersive exergames. Although there are studies that focus on the safety of older adults exercising through technologies, they are not self-reported by the users, but rather, the relevant data are obtained through objective techniques [65,66]. Behavioral acceptance of exercise as a physical activity in older adults in conjunction with virtual reality technology should focus on their perceived physical environment and physical safety. In addition, the exercise posture adopted by the user was proposed as a factor in the theoretical model having a significant effect on PE and PPS. The analyses verified that the measurement items of the PPS were reliable and had acceptable validity.

Further, older adults were not as concerned about the perceived physical safety of immersive exercise compared to previously studied concerns about safety [67–69]. Instead, perceived physical safety was negatively related to the acquisition of health performance expected by older adults, and standing posture was expected to be higher for PE compared to sitting posture. Future immersive exergame designs for older adults could, therefore, go beyond upper limb-only activities such as sitting. To a certain extent, immersive exergames with standing postures and a certain amount of movement space can give older adults more stimulation and a better game experience. In addition, users with standing posture expect more health benefits from immersive exergames.

6.3. Limitations and Future Work

Some cautions should be paid attention to in the study findings. First, due to equipment and venue limitations, the frequency of immersion exercises performed by one participant was only once and not representative of long-term feelings and acceptance. Second, facilitating conditions and social influence were not measured in this study, and additional factors will be added in subsequent experiments with multi-user testing. Third, during this experiment, the participants were not alone in the immersion exercise during the experiment but were surrounded by other older adults who were not participating or had finished participating. Therefore, the surrounding physical environment and the crowd may have had some influence on the results of the experiment. For example, in terms of perceived safety, sound localization may have an impact on perceived physical safety due to the continuous presence of sounds from other people in the surrounding physical environment. Secondly, in terms of the results of willingness to use, the crowd and friends around the participants making them excited may have been the reason for the generally higher scores. The sounds of the physical environment, as well as the surrounding crowd, should be controlled during subsequent experiments.

7. Conclusions

In this study, performance expectancy and effort expectancy of the universal UTAUT model were tested in the situation of immersive exergames among older adults. Two predictors were developed as supplementary predictive factors for this extended UTAUT model were proposed and validated. Perceived physical safety yields a predicting influence of performance expectancy, sitting and standing postures significantly correlated with PPS and PE. The study also offers the general perceptions and intentions of acceptance behaviors from Chinese older adults. Especially, their attitudes towards safety issues when using immersive technologies like virtual reality. This study showed that safety perceptions can be studied for older adults to predict their performance expectancy for the future. Furthermore, the physical postures should be considered when designing immersive exergames, and more possibilities can be investigated in the future, for example, lying and sitting positions without chairs.

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